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CONTENTS

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by

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## Abstract

A theoretical investigation of thermal conductance of two-dimensional eccentric constrictions has been carried out. By the use of conformal transformations, a closed form exact analytical solution has been obtained. The solution has been presented in terms of three dimensionless numbers - a conductance number, a constriction number and an eccentricity number. The theory has been checked with previously reported experimental results. The agreement is excellent. It has also been compared with two analytical expressions reported earlier.

## Introduction

When heat flows by conduction through parts of equipment, in many instances, it is abruptly constricted to small cross-sectional areas, or when it flows through surfaces in contact it is always forced to pass through smaller cross-sectional areas, as compared to flow areas away from such abrupt constrictions. As a result of the convergence and divergence of heat flow lines at and near such a constriction, a thermal resistance (or conductance) develops. This resistance is usually quite high compared to the resistance offered to heat flow away from the constriction. For a reliable heat transfer analysis of a given system, such constriction resistances must be accurately predicted in addition to other parameters.

The simplest constrictions are two-dimensional constrictions where the constriction geometry is a function of two rectangular co-ordinates only. The conductances of two-dimensional symmetrical constrictions have been investigated by Kouwenhoven and Sackett[1], Sackett[2], Mikic and Rohsenow[3], and Veziroglu and Chandra[4] both theoretically and experimentally. Veziroglu and Chandra obtained the exact solution of the problem which agreed very well with the experimental results. The above mentioned researchers, with the exception of Mikic and Rohsenow, also investigated the conductances of two-dimensional eccentric constrictions. They all reported some experimental studies, and additionally Sackett, and Veziroglu and Chandra derived analytical expressions for calculating the conductances of two-dimensional eccentric constrictions by making some simplifying assumptions. Sackett assumed that only a wedge-like part (made up of sides starting at constriction edges and extending to flow channel boundaries by making a certain angle with the constriction plane) of the flow channel near the constriction was effective in conducting electricity (or heat), calculated its resistance, and presented the result as the percentage increase in resistance of an eccentric constriction with respect to that of a symmetrical constriction of the same size. This expression would predict lower resistances (or higher conductances) than those obtained experimentally by up to 5 per cent. Veziroglu and Chandra replaced the constant temperature condition at the constriction by a uniform flux distribution and obtained a series expression for the conductance of the eccentric constrictions which gave quite a good agreement with the experimental results. However, it had the disadvantage of being in the form of inifinite series.

## Theory

Fig. 1 shows the steady state isotherms and heat flow lines for a two-dimensional eccentric constriction. The heat flow channel width is 2a, the constriction width 2b, the eccentricity (the distance between the centerline of the heat flow channel and the centerline of constriction) e, and the channel thickness t. Because of the symmetry, it will suffice to consider only one of the half planes, e.g., the one defined by $y \geq o$. The steady state temperature distribution must satisfy the Laplace's equation,

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the following boundary conditions,

$$\left(\frac{\partial T}{\partial x}\right)_{x=a} = 0 \qquad o < y < \infty \quad . \quad . \quad (2)$$

$$\left(\frac{\partial T}{\partial x}\right)_{x=-a} = 0 \qquad o < y < \infty \quad . \quad . \quad (3)$$

$$\left(\frac{\partial T}{\partial y}\right)_{y=0} = 0 \qquad -a < x < e-b \quad . \quad . \quad (4)$$

$$\left(\frac{\partial T}{\partial y}\right)_{y=0} = 0 \qquad e+b < x < a \quad . \quad (5)$$

$$(T)_{y=o} = \text{Constant} \qquad e-b < x < e+b \quad . \quad (6)$$

The temperature distribution satisfying equation (1) and conditions (2) through (6) can be reduced to a very simple, linear, temperature distribtution by means of three conformal transformations. Fig. 2 illustrates these transformations. Fig. 2A shows the boundaries of the problem posed in the complex z plane. The temperature slope is zero along the boundaries ABC and DEF, and the temperature is constant along the boundary CD. These boundaries can be transformed to the boundaries shown in Fig. 2B by means of the conformal transformation of

$$z_1 = \sin\left(\frac{\pi z}{2a}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

which preserves the Laplace's relationship and the boundary conditions along the transformed boundaries. The distances $O_1C_1$ and $O_1D_1$ in the complex $z_1$ plane are, with the help of the transformation relationship (7), given by

$$O_1C_1 = \sin\frac{\pi \cdot OC}{2a}$$

or $$O_1C_1 = \sin \left\{\frac{\pi(e-b)}{2a}\right\} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and $$O_1D_1 = \sin \frac{\pi \cdot OD}{2a}$$

or $$O_1D_1 = \sin \left\{\frac{\pi(e+b)}{2a}\right\} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Now a second transformation will be carried out in order to bring the ordinate to the middle of the transformed constriction $C_2D_2$ (See Fig. 2C). This can be achieved by means of the conformal transformation of

$$z_2 = z_1 - \frac{1}{2}\{O_1C_1 + O_1D_1\} \quad . \quad . \quad . \quad . \quad (10)$$

Substituting equations (8) and (9) in (10), $z_2$ becomes

$$z_2 = z_1 - \frac{1}{2}\left\{\sin \frac{\pi(e-b)}{2a} + \sin \frac{\pi(e+b)}{2a}\right\} \quad . \quad . \quad . \quad (11)$$

Because of the transformation relationship (11), the distances $O_2C_2$ and $O_2D_2$ in the complex $z_2$ plane are given by

$$O_2C_2 = -\frac{1}{2}\left\{\sin \frac{\pi(e+b)}{2a} - \sin \frac{\pi(e-b)}{2a}\right\} \quad . \quad . \quad . \quad . \quad (12)$$

and $$O_2D_2 = \frac{1}{2}\left\{\sin \frac{\pi(e+b)}{2a} - \sin \frac{\pi(e-b)}{2a}\right\} \quad . \quad . \quad . \quad . \quad (13)$$

which shows that the new ordinate is located in the middle of the transformed constriction.

The boundaries shown in Fig. 2C can be transformed into the boundaries shown in Fig. 2D by means of the conformal transformation of

$$z_3 = \frac{2a}{\pi} \sin^{-1}\{\frac{z_2}{O_2D_2}\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . (14)$$

Substituting equation (13) in (14), and inverting, one obtains

$$z_2 = \frac{1}{2}\{\sin \frac{\pi(e+b)}{2a} - \sin \frac{\pi(e-b)}{2a}\}\sin \frac{\pi z_3}{2a} \quad . \quad . \quad . (15)$$

Substituting equation (7) in (11), and the resulting expression in equation (15), the transformation relationship between the complex z and $z_3$ planes becomes

$$\sin(\frac{\pi z}{2a}) = \sin(\frac{\pi e}{2a}) \cdot \cos(\frac{\pi b}{2a}) + \sin(\frac{\pi b}{2a})\cos(\frac{\pi e}{2a})\sin(\frac{\pi z_3}{2a}) \quad (16)$$

which again preserves the Laplace's relationship and the boundary conditions along the transformed boundaries. Writing $z=x + iy$ and $z_3= x_3+ iy_3$ in the transformation relationship (16) and considering the real and imaginary terms, one obtains the following relationships between the coordinates in z and $z_3$ planes:

$$\sin(\frac{\pi x}{2a})\cosh(\frac{\pi y}{2a}) = \sin(\frac{\pi e}{2a})\cos(\frac{\pi b}{2a}) + \sin(\frac{\pi b}{2a})\cos(\frac{\pi e}{2a})\sin(\frac{\pi x_3}{2a})\cosh(\frac{\pi y_3}{2a}) \quad . \quad . \quad . (17)$$

and $$\cos(\frac{\pi x}{2a})\sinh(\frac{\pi y}{2a}) = \sin(\frac{\pi b}{2a})\cos(\frac{\pi e}{2a})\cos(\frac{\pi x_3}{2a})\sinh(\frac{\pi y_3}{2a}) \quad (18)$$

For heat flow along the constant width (2a) and no constriction channel shown in Fig. 2D, the steady temperature distribution is given by

$$T = my_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where m is a constant. Equation (19) satisfies the Laplace's equation and the transformed boundary conditions of (2) through (6). The constant temperature at the constriction has been taken as zero for convenience.

Eliminating $x_3$ between equations (17) and (18), solving for $y_3$, substituting for $y_3$ in equation (19), the temperature distribution T in terms of the original coordinates and geometry becomes

$$T = \frac{ma}{\pi}\cosh^{-1}\left\{ \frac{[\sin(\frac{\pi x}{2a})\cosh(\frac{\pi y}{2a}) - \sin(\frac{\pi e}{2a})\cos(\frac{\pi b}{2a})]^2 + \cos^2(\frac{\pi x}{2a})\sinh^2(\frac{\pi y}{2a})}{\sin^2(\frac{\pi b}{2a})\cos^2(\frac{\pi e}{2a})} \right.$$

$$\pm \left[ \frac{\{[\sin(\frac{\pi x}{2a})\cosh(\frac{\pi y}{2a}) - \sin(\frac{\pi e}{2a})\cos(\frac{\pi b}{2a})]^2 + \cos^2(\frac{\pi x}{2a})\sinh^2(\frac{\pi y}{2a}) - \sin^2(\frac{\pi b}{2a})\cos^2(\frac{\pi e}{2a})\}^2}{\sin^4(\frac{\pi b}{2a})\cos^2(\frac{\pi e}{2a})} \right.$$

$$\left.\left. + \frac{4\cos^2(\frac{\pi x}{2a})\sinh^2(\frac{\pi y}{2a})}{\sin^2(\frac{\pi b}{2a})\cos^2(\frac{\pi e}{2a})}\right]^{1/2} \right\} \quad . \ . \ . \ . \ . \ . \ . \quad (20)$$

The thermal resistance introduced as a result of the constriction in the heat flow channel can be defined as

$$R_c = \frac{\Delta T_c}{H} \quad . \ . \ . \ . \ . \ . \ . \ . \quad (21)$$

where $\Delta T_c$ is the additional temperature drop produced by the constriction and H the heat flow rate in the channel. The temperature drop $\Delta T_c$ can be calculated from

$$\Delta T_c = \lim_{y\to\infty} \{T - y\frac{\partial T}{\partial y}\} \quad . \ . \ . \ . \ . \quad (22)$$

In this equation the first term within the brackets represents the actual temperature drop between y=∞ and y=o (constriction) and the second term the temperature drop between the same two points if there were no constriction. Substituting equation (20) in (22) and taking the limit, the constriction temperature drop becomes

$$\Delta T_c = \frac{2am}{\pi} \ln\{\frac{1}{\cos(\frac{\pi e}{2a})\sin(\frac{\pi b}{2a})}\} \quad . \quad . \quad . \quad (23)$$

The heat flow rate H can be calculated from

$$H = (\text{Channel C.S.A.})(\text{Thermal Conductivity})\left(\frac{\partial T}{\partial y}\right)_{y=\infty}$$

or

$$H = 2\ at\ k\left(\frac{\partial T}{\partial y}\right)_{y=\infty} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

From equation (20), the temperature slope at $y=\infty$ is,

$$\left(\frac{\partial T}{\partial y}\right)_{y=\infty} = m \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

Substituting equation (25) in (24), the heat flow rate becomes

$$H = 2amtk \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

Substituting equations (23) and (26) in (21), the thermal constriction resistance (for one side of the constriction) is found to be

$$R_c = \frac{1}{\pi tk} \ln\{\frac{1}{\cos(\frac{\pi e}{2a})\sin(\frac{\pi b}{2a})}\} \quad . \quad . \quad . \quad (27)$$

The constriction conductance per unit area of the flow channel, by definition, is,

$$u = \frac{1}{(\text{Channel C.S.A.})R_c}$$

or

$$u = \frac{\pi k}{2a \ln\left\{\frac{1}{\cos\left(\frac{\pi e}{2a}\right)\sin\left(\frac{\pi b}{2a}\right)}\right\}} \quad . \quad . \quad . \quad . \quad (28)$$

The number of variables in the above equation can be reduced by introducing three dimensionless numbers, a constriction conductance number U, a constriction number C, and an eccentricity number E, defined as follows:

$$U = \frac{u(\text{Channel Width})}{k} = \frac{2au}{k} \quad . \quad . \quad . \quad (29)$$

$$C = \frac{(\text{Constriction Width})}{(\text{Channel Width})} = \frac{2b}{2a} = \frac{b}{a} \quad . \quad (30)$$

and $$E = \frac{2(\text{Eccentricity Width})}{(\text{Channel Width})-(\text{Constriction Width})} = \frac{e}{a-b} \quad (31)$$

The eccentricity number E, defined by equation (31) varies between 0 and 1 for a given constriction number C. Equation (28) can now be written in dimensionless form by using equations (29), (30) and (31), resulting in the following expression

$$U = \frac{\pi}{\ln\left\{\frac{1}{\sin\left(\frac{\pi C}{2}\right)\cos\left[\frac{\pi E}{2}(1-C)\right]}\right\}} \quad . \quad . \quad . \quad . \quad (32)$$

A study of the above expression shows that the constriction conductance number U increases with increase in the constriction number C, decreases with increase in the eccentricity number E, and reaches one-half of the value for the symmetrical case when E has its maximum value of unity.

For no eccentricity, in other words for E=0, equation (32) reduces to

$$U_o = \frac{\pi}{\ln\{\frac{1}{\sin(\frac{\pi C}{2})}\}} \quad . \quad . \quad . \quad . \quad . \quad (33)$$

which is same as the expression obtained for the thermal conductance of two-dimensional symmetrical constrictions in reference (4). Dividing equation (32) by (33), the ratio of the constriction conductance number for a given eccentricity to that for zero eccentricity becomes

$$\frac{U}{U_o} = \frac{\ln\{\sin(\frac{\pi C}{2})\}}{\ln\{\sin(\frac{\pi C}{2})\cos[\frac{\pi E}{2}(1-C)]\}} \quad . \quad . \quad . \quad (34)$$

This ratio varies between 0.5 and 1 depending on the values of the dimensionless numbers C and E which can vary between 0 and 1.

## Discussion

The results of the present investigation and references (2) and (4) are plotted in Figs. 3, 4 and 5 as the ratio of the constriction conductance number to that of zero eccentricity $U/U_o$ versus the eccentricity number E for the constriction numbers of 0.04, 0.08 and 0.125 respectively, since experimental data were available for these values of E. The experimental points are those of Sackett[2] for

C = 0.04 and C = 0.08, and of Veziroglu and Chandra[4] for C = 0.125. In the two experimental investigations electrical analogy was used. The theoretical curves were obtained from the present theory using the appropriate values of the constriction number C and also from the relationships derived by Sackett, and Veziroglu and Chandra. In his theory, Sackett employing the wedge model described earlier obtained a relationship for the ratio of the resistance increase due to eccentricity to the constriction resistance for zero eccentricity. In terms of the present dimensionless numbers, it can be written as

$$\frac{U}{U_o} = \frac{\ln(\frac{1}{C}) + C-1}{\ln\{\frac{1}{C(1-E+EC)}\} - (1+E)(1-C)} \quad . \quad . \quad (35)$$

For the same ratio, Veziroglu and Chandra - assuming a uniform flux distribution at the constriction - obtained the following relationship

$$\frac{U}{U_o} = \frac{\sum_{n=1}^{\infty} \frac{1}{n^3}\sin^2(n\pi C)}{8\sum_{n=1}^{\infty} \frac{1}{n^3}\sin^2(\frac{n\pi}{2}C)\cos^2[\frac{n\pi}{2}(1+E-EC)]} \quad . \quad . \quad (36)$$

The constriction flux distribution q' employed in the derivation of the above equation can be expressed by

$$q' = \frac{H}{2bt} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

where H is the total heat flow rate in the channel containing the constriction. Using equation (20), it can be shown that the correct flux distribution q at the constriction would be

$$q = k\left(\frac{\partial T}{\partial y}\right)_{y=o}$$

$$\text{or}\quad q = \frac{H \cos\left(\frac{\pi x}{2a}\right)}{2at\sqrt{\cos^2\left(\frac{\pi e}{2a}\right)\sin^2\left(\frac{\pi b}{2a}\right)-\left[\sin\left(\frac{\pi x}{2a}\right)-\sin\left(\frac{\pi e}{2a}\right)\cos\left(\frac{\pi b}{2a}\right)\right]^2}} \quad . \quad . \quad . \quad . \quad . \quad (38)$$

This relationship shows that the constriction flux distribution is not uniform but somewhat parabolic in form such that it is infinite at the constriction edges (i.e., for x=e-b and x=e+b) and reaches a minimum in between.

From Figs. 3, 4 and 5, it can be seen that the agreement between the experimental data and two of the theories, the present theory and the theory of reference (4), is quite good. It is interesting to note that although the constriction flux distribution assumed in reference (4) was an over-simplification of the actual distribution the conductance ratio is in good agreement with the experiments and the present theory. However, the present theory, in addition to being the exact solution, has the advantage of being in a very compact form as compared to the infinite series form of the theory of reference (4). The agreement between the experimental data and the theory of reference (2) is not so good, except for the extreme values of the eccentricity number E (i.e., for E=o and E=1).

In order to compare the present theory with two previous theories for a wider range of the constriction number than that covered in Figs. 3 through 5, Table I has been prepared. It lists the values of the conductance ratios for the three theories and also the percentage divergences of the theories of references (2) and (4) from the exact solution, the present theory, for various combinations of the constriction number and the eccentricity number. It can be seen from the table that at the two extreme values of the eccentricity number all the theories give the same result for the conductance ratio. However, in between the extreme values of the eccentricity number, the conductance ratio values of the theory of reference (2) is greater by as much as 4.8% than those obtained from the exact theory, and the conductance ratio values of the theory of reference (4) is also greater but to a smaller extent with a maximum divergence of 1.9%. It must be noted here that in the evaluation of equation (36) for Table I, the first forty terms of the infinite series were used. If more terms were used, the maximum divergence would have been less than 1.9%.

## Conclusion

One closed form equation is derived for calculating the exact thermal conductance of two-dimensional eccentric constrictions. The agreement between the theory and experimental data is good. Thermal conductance of two-dimensional constrictions increase with (a) increase in thermal conductivity, (b) increase in constriction width, (c) decrease in channel width, and (d) decrease in eccentricity.

## Acknowledgements

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## Nomenclature

### Symbols

| | |
|---|---|
| A | Point in flow channel boundary |
| a | Half width of Heat Flow Channel |
| B | Point in flow channel boundary |
| b | Half width of Constriction |
| C | Constriction Number (=b/a); Point in flow channel boundary |
| D | Point in flow channel boundary |
| E | Eccentricity Number (=e/(a-b)); Point in flow channel boundary |
| e | Eccentricity |
| F | Point in flow channel boundary |
| H | Heat flow rate |
| i | $\sqrt{-1}$ |
| k | Thermal conductivity |
| ln | Natural logarithm |
| m | Proportionality factor; Temperature slope away from constriction |
| n | Number |
| O | Origin; Point in flow channel boundary |
| q | Thermal flux |
| R | Resistance |
| T | Temperature |
| t | Flow channel thickness |
| U | Conductance Number (=2au/k) |
| u | Constriction conductance per unit area |
| x | Abscissa in two-dimensional plane; Abscissa in complex z plane |
| y | Ordinate in two-dimensional plane; Ordinate in complex z plane |
| z | Complex plane |
| $\Delta$ | Difference |

<u>Subscripts</u>

| | |
|---|---|
| c | Constriction |
| o | No-constriction |
| 1 | First transformation |
| 2 | Second transformation |
| 3 | Third transformation |

TABLE I

COMPARISON OF PRESENT THEORY WITH PREVIOUS THEORIES

| Constriction Number | Eccentricity Number | Present Conductance Ratio $(U/U_o)_1$ | Conductance Ratio of Reference (2) $(U/U_o)_2$ | Conductance Ratio of Reference (4) $(U/U_o)_4$ | $100\text{x}\frac{(U/U_o)_2-(U/U_o)_1}{(U/U_o)_1}$ | $100\text{x}\frac{(U/U_o)_4-(U/U_o)_1}{(U/U_o)_1}$ |
|---|---|---|---|---|---|---|
| 0.1 | 0.0 | 1.000 | 1.000 | 1.000 | 0.0 | 0.0 |
| 0.1 | 0.2 | 0.979 | 0.987 | 0.982 | 0.9 | 0.3 |
| 0.1 | 0.4 | 0.916 | 0.942 | 0.922 | 2.8 | 0.6 |
| 0.1 | 0.6 | 0.818 | 0.856 | 0.826 | 4.7 | 1.1 |
| 0.1 | 0.8 | 0.685 | 0.717 | 0.695 | 4.8 | 1.6 |
| 0.1 | 1.0 | 0.500 | 0.500 | 0.500 | 0.0 | 0.0 |
| 0.3 | 0.0 | 1.000 | 1.000 | 1.000 | 0.0 | 0.0 |
| 0.3 | 0.2 | 0.970 | 0.979 | 0.973 | 0.9 | 0.3 |
| 0.3 | 0.4 | 0.887 | 0.912 | 0.895 | 2.8 | 0.9 |
| 0.3 | 0.6 | 0.770 | 0.802 | 0.782 | 4.1 | 1.6 |
| 0.3 | 0.8 | 0.637 | 0.659 | 0.649 | 3.5 | 1.9 |
| 0.3 | 1.0 | 0.500 | 0.500 | 0.500 | 0.0 | 0.0 |
| 0.5 | 0.0 | 1.000 | 1.000 | 1.000 | 0.0 | 0.0 |
| 0.5 | 0.2 | 0.965 | 0.973 | 0.968 | 0.8 | 0.3 |
| 0.5 | 0.4 | 0.873 | 0.893 | 0.882 | 2.3 | 1.0 |

TABLE I (Continued)

COMPARISON OF PRESENT THEORY WITH PREVIOUS THEORIES

| Constriction Number | Eccentricity Number | Present Conductance Ratio $(U/U_o)_1$ | Conductance Ratio of Reference (2) $(U/U_o)_2$ | Conductance Ratio of Reference (4) $(U/U_o)_4$ | $100\text{x}\frac{(U/U_o)_2-(U/U_o)_1}{(U/U_o)_1}$ | $100\text{x}\frac{(U/U_o)_4-(U/U_o)_1}{(U/U_o)_1}$ |
|---|---|---|---|---|---|---|
| 0.5 | 0.6 | 0.750 | 0.773 | 0.763 | 3.1 | 1.7 |
| 0.5 | 0.8 | 0.620 | 0.635 | 0.631 | 2.5 | 1.8 |
| 0.5 | 1.0 | 0.500 | 0.500 | 0.500 | 0.0 | 0.0 |
| 0.7 | 0.0 | 1.000 | 1.000 | 1.000 | 0.0 | 0.0 |
| 0.7 | 0.2 | 0.963 | 0.968 | 0.966 | 0.5 | 0.3 |
| 0.7 | 0.4 | 0.866 | 0.879 | 0.874 | 1.5 | 0.9 |
| 0.7 | 0.6 | 0.740 | 0.754 | 0.751 | 2.0 | 1.5 |
| 0.7 | 0.8 | 0.612 | 0.622 | 0.621 | 1.6 | 1.4 |
| 0.7 | 1.0 | 0.500 | 0.500 | 0.500 | 0.0 | 0.0 |
| 0.9 | 0.0 | 1.000 | 1.000 | 1.000 | 0.0 | 0.0 |
| 0.9 | 0.2 | 0.961 | 0.964 | 0.964 | 0.2 | 0.3 |
| 0.9 | 0.4 | 0.862 | 0.867 | 0.867 | 0.6 | 0.6 |
| 0.9 | 0.6 | 0.734 | 0.741 | 0.740 | 0.9 | 0.8 |
| 0.9 | 0.8 | 0.608 | 0.613 | 0.613 | 0.8 | 0.7 |
| 0.9 | 1.0 | 0.500 | 0.500 | 0.500 | 0.0 | 0.0 |

## List of Figures

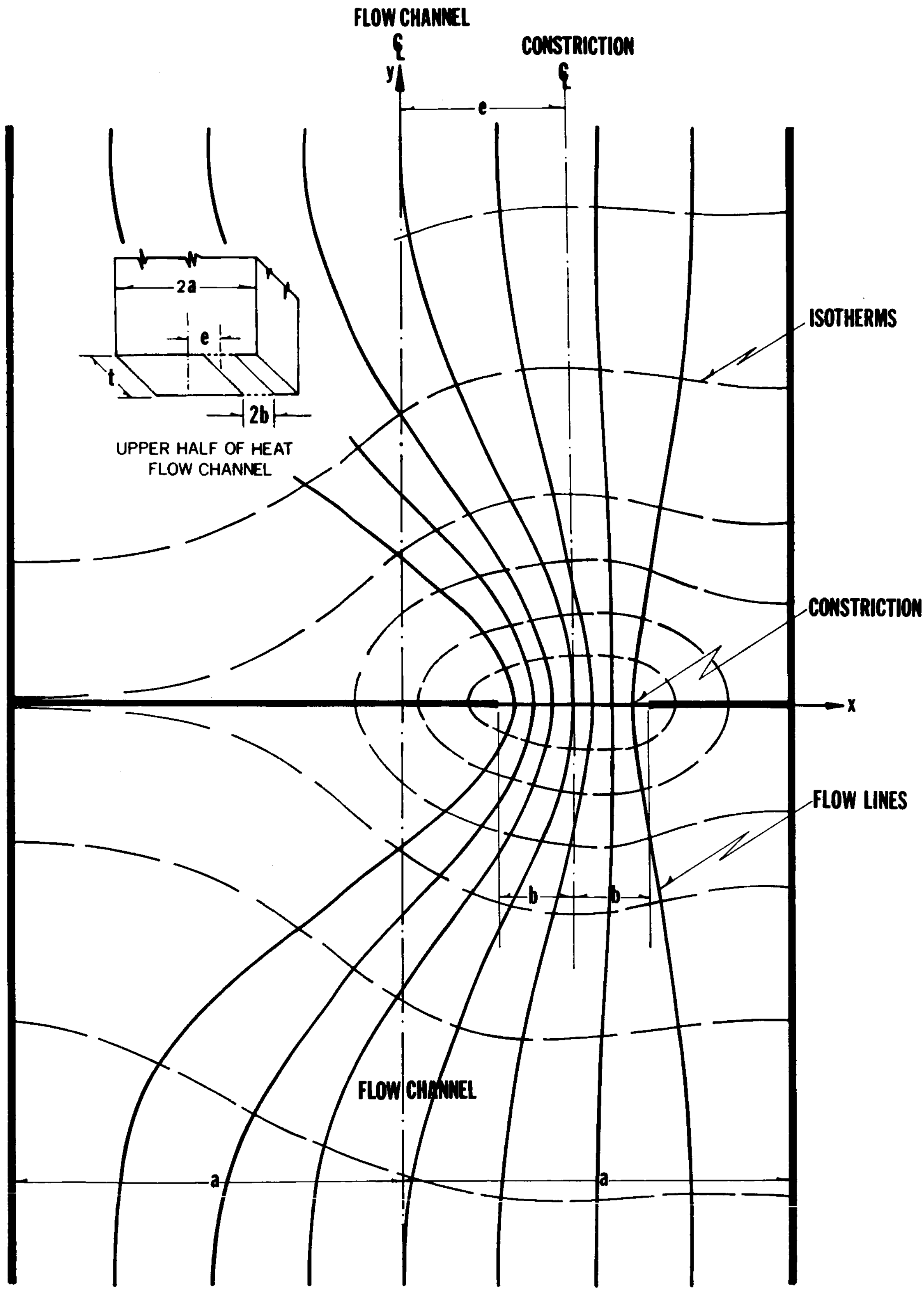


FIG.1.- HEAT FLOW LINES AND ISOTHERMS IN A TWO DIMENSIONAL ECCENTRIC CONSTRICTION

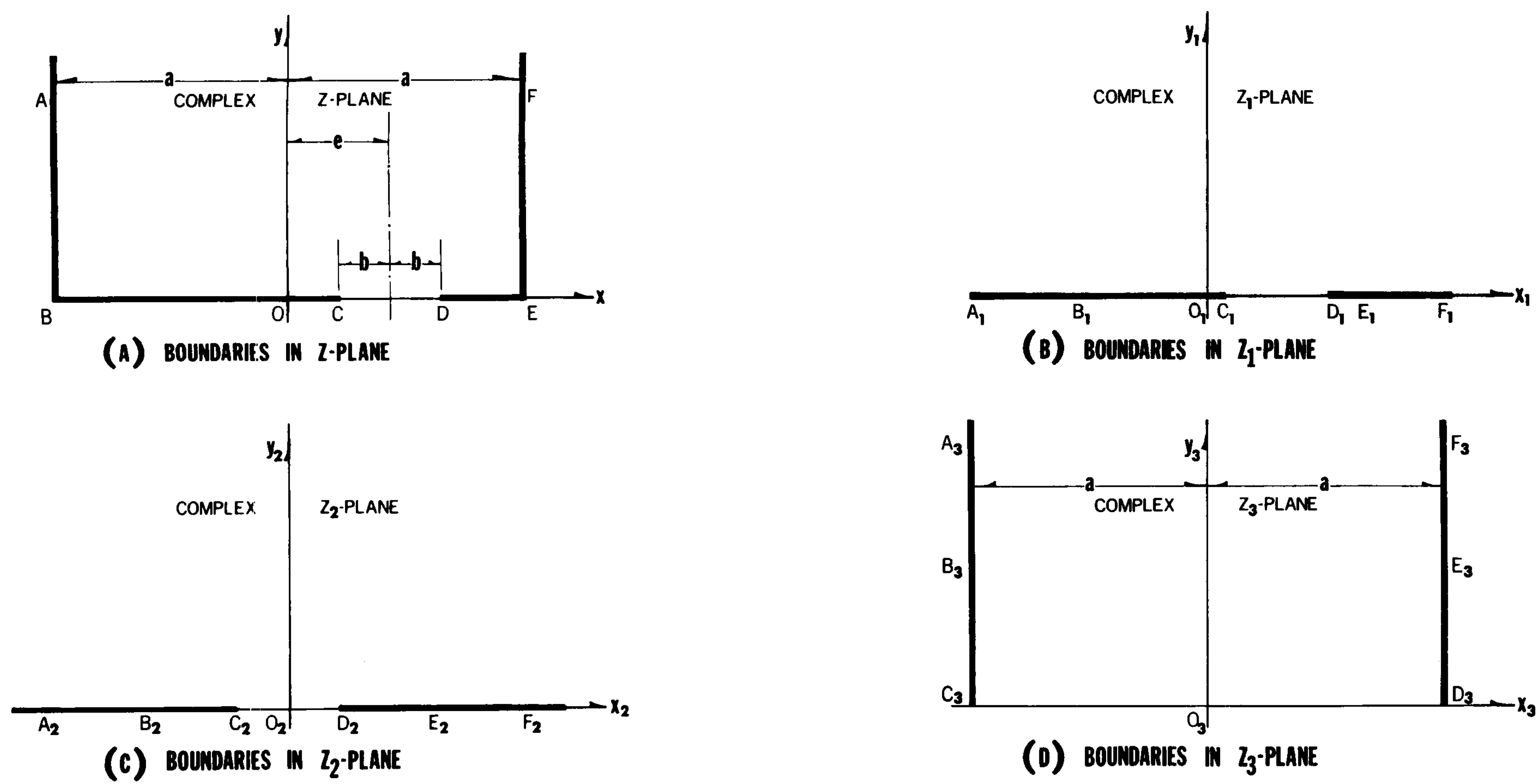


**FIG.2.- CONFORMAL TRANSFORMATIONS FOR SIMPLIFYING BOUNDARY CONDITIONS OF TEMPERATURE DISTRIBUTION IN A TWO DIMENSIONAL ECCENTRIC CONSTRICTION**

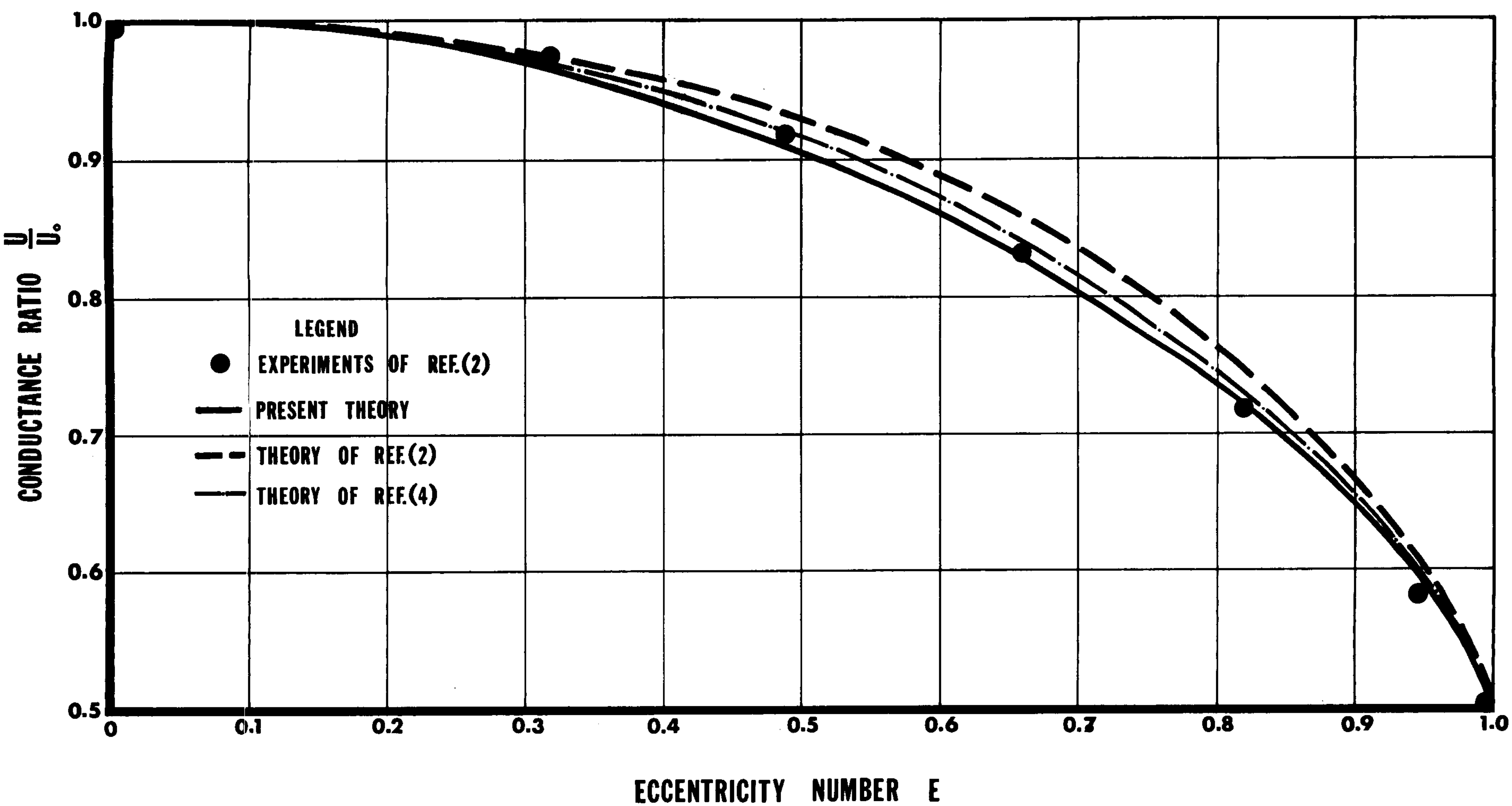


FIG.3. EXPERIMENTAL AND THEORETICAL RELATIONSHIPS BETWEEN CONDUCTANCE RATIO AND ECCENTRICITY NUMBER FOR C=0.04

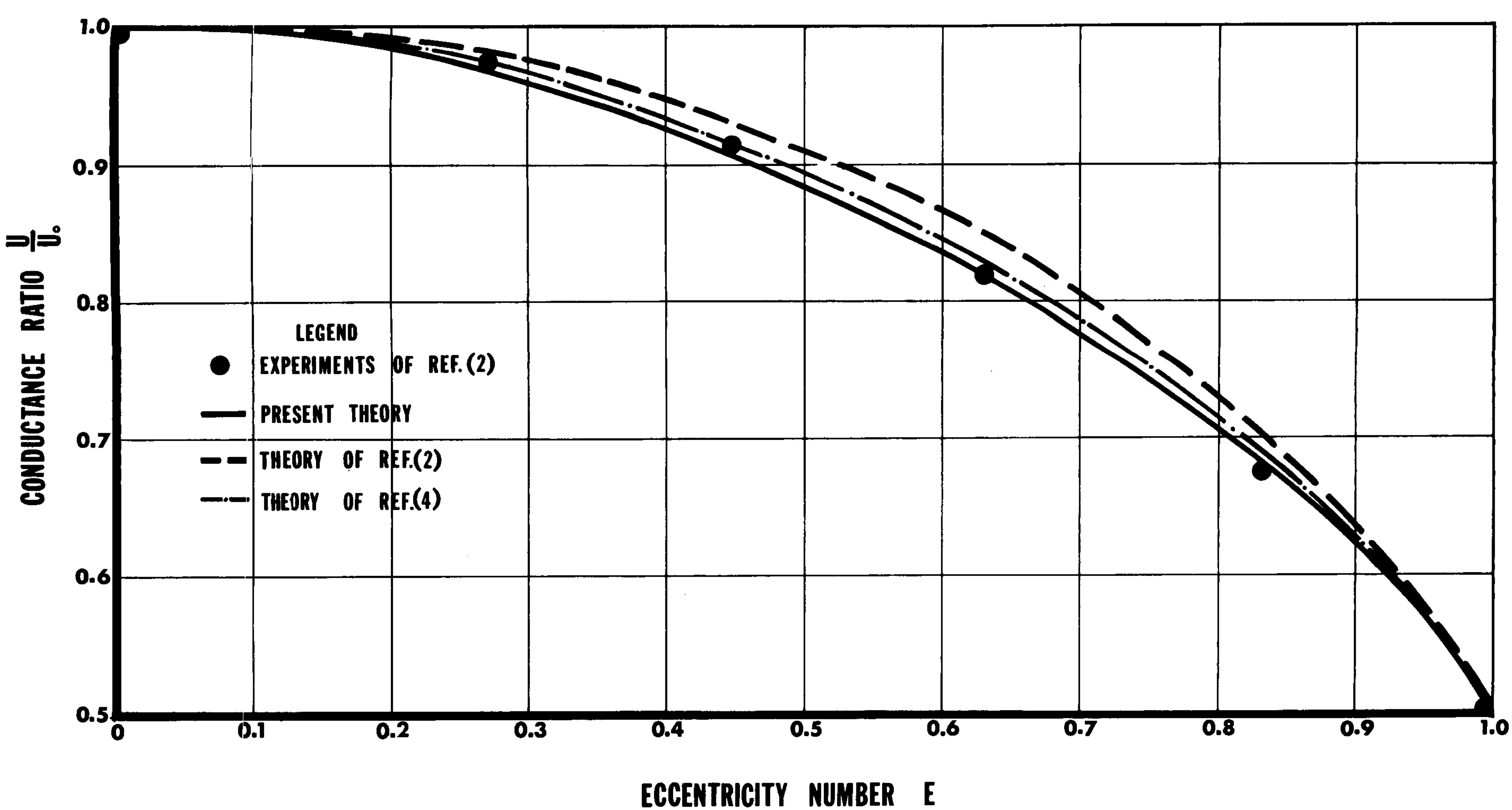


FIG.4. EXPERIMENTAL AND THEORETICAL RELATIONSHIPS BETWEEN CONDUCTANCE RATIO AND ECCENTRICITY NUMBER FOR C = 0.08

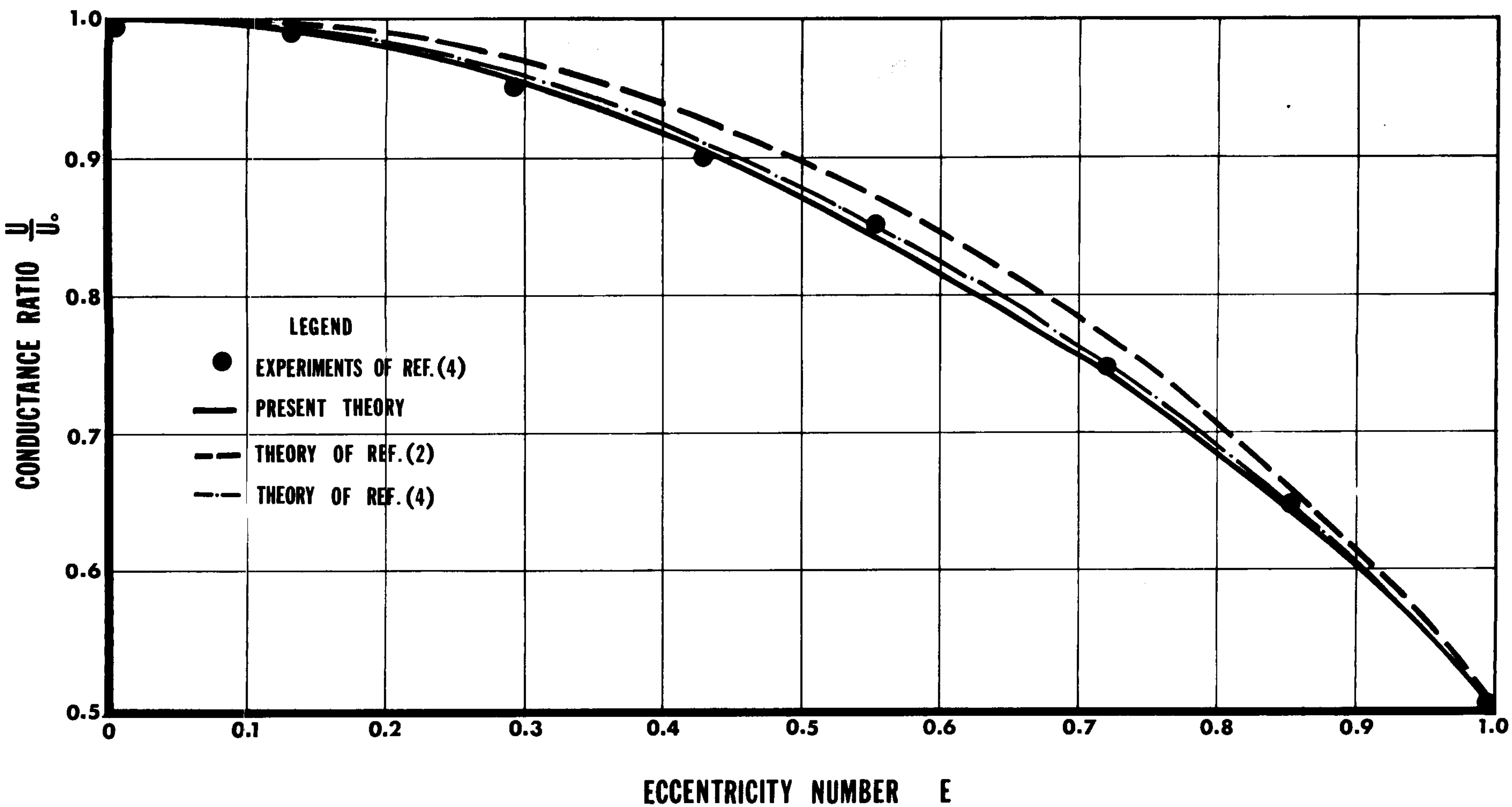


FIG.5. EXPERIMENTAL AND THEORETICAL RELATIONSHIPS BETWEEN CONDUCTANCE RATIO AND ECCENTRICITY NUMBER FOR C = 0.125